Feedbacks between plant biomass and soil microbial activity in a field-based experimental warming treatment

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Introduction

Climate change is disrupting the function and stability of semiarid grassland ecosystems and soil resources through direct effects on soil microbiota and plant-microbe interactions. Using field soils and near-infrared reflector mirrors, we examined the effects of warming, soil nutrients, and texture on native plant growth and microbial community activity. Temperature is known to shift bacteria and fungal ratios in soils due to their differing thermal sensitivities, and these shifts determine hydrolytic extracellular enzyme production and rates of activity (EEA). Physiochemical soil properties further contribute to the fate of extracellular enzymes and need to be further considered under changing temperature and moisture regimes. Ongoing research is aimed at quantifying the feedbacks between plant and microbial communities under these warmer and dried conditions.

Hypotheses

- H1: The different soil physiochemical properties of our experimental soils (e.g., pH, water holding capacity, texture) will affect plant biomass and EEA.
- H2: Warming increases evaporative demand, causing drier soils that could reduce plant biomass and microbial biomass and activity.
- H3: Warming should cause a shift in the microbial community composition depending on whether fungi or bacteria are more sensitive. If fungi more sensitive to warming there should be a decline in the variety and quality of carbon substrates that are able to be consumed.

Study Site and Methods

Soils from two common soil types, loamy sand and sandy loam, were collected from the Santa Rita Mountains, AZ. Using a fully factorial design, the effects of warming, soil nutrients, and texture on native plant growth and microbial community activity were tested. After 95 days, soil samples were collected and analyzed plant biomass, EEA, and standard biogeochemistry. To determine plant biomass, plots were clipped to 2cm and resulting biomass was dried at 70 C for 48 hours. EEA was analyzed using a Biotek microplatereader by quantifying fluorescent dye as it was emitted by an enzyme catalyzed reaction.

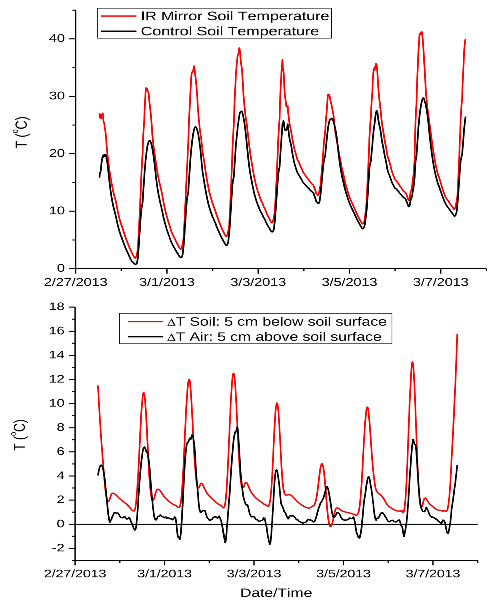


Fig 1a. Near-infrared reflector (IR) mirrors (750-1150 nm) were used to passively warm soil plots by augmenting the long-wave radiation flux from sunlight. Soils were warmed by an average of 3.5 °C, which is consistent with the range projected by climate forecasting models.
Fig 1b. Temperature responses to IR mirrors versus controls. Air temperature measurement 5 cm above the soil surface and soil temperature measurement 5 cm below the soil surface were logged for 96 hours. Main extra heating occurs via peak heat mid-day, with sustained warmer soil temps overnight. Note the shading effect of mirrors in the early morning hours.

Results

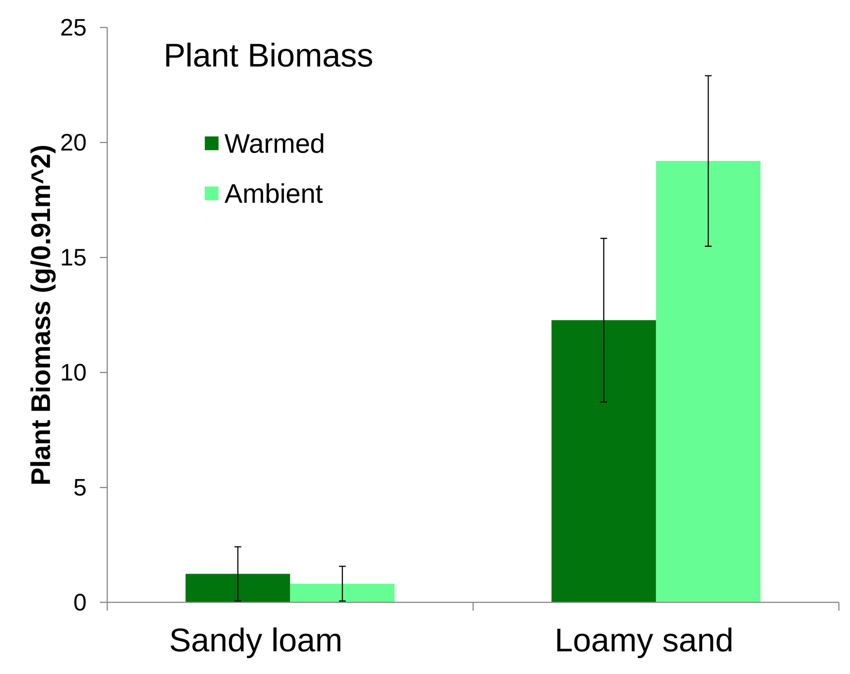
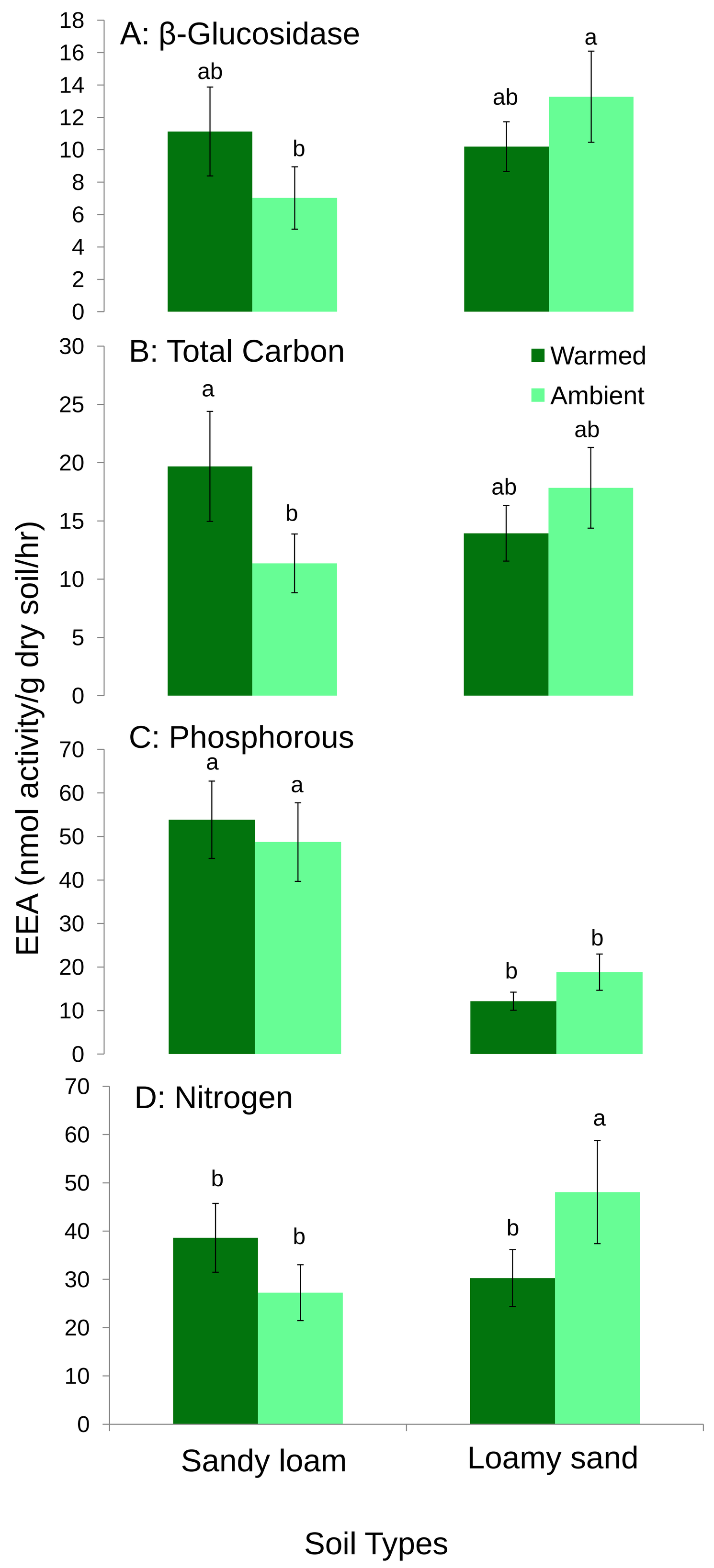


Fig. 2a. Plant biomass was driven by soil type (R Package 3.1.3, MANOVA; F=30.5, P<0.001). Loamy sand soils yielded the highest plant biomass, with ambient temperature plots resulting in higher yields than warmed plot. Few plants established in sandy loam soils, and warming had no effect on plant biomass. **Fig 2b**. Representative plant biomass plots in warmed and ambient sandy loam (left) and loamy sand (right).

Fig 3. Average extracellular enzyme activity (EEA) for different organic molecules. All EEA were driven by soil type (R Package 3.1.3, MANOVA; F=15.5, P<0.001). **(A)** β-Glucosidase (BG), which represents simple sugar degradation (F=18.8, P<0.01). **(B)** Total Carbon is a compilation of simple sugars including BG and α-Glucosidase (AG) along with β-Xylosidase (XYL) and β-D-cellobioside (CB), which are more complex carbon molecules. (F=32.7, P<0.001) **(C)** Represents Phosphorous (P) mineralization (F=19.7, P<0.001) **(D)** Nitrogen mineralization, including leucine aminopeptidase (LAP) and N-acetyl- β -D-glucosaminide (NAG) (F=24.9, P<0.001).



The warming effect was not consistent across soil types. For sandy loam soils, total EEA was higher in warmed plots than in ambient plots, while the opposite was true in loamy sand. Phosphorous mineralization rates were significantly higher in sandy loam, and warming did not change mineralization rates in either soil type.

Soil type, not warming, had the strongest effect on plant biomass and rates of phosphorous mineralization, with sandy loam soils supporting lowest plant biomass and highest rates of P mineralization.

Discussion

Different water holding capacities of loamy sand and sandy loam provide alternate challenges for **plant establishment**, especially during periods of low precipitation. The relatively lower clay content and water-holding capacity of loamy sand may cause an increase in evaporation potential and a decrease in hydraulic conductivity when warmed (Fehmi & Kong, 2012). Plant recruitment in well-drained loamy sand could be challenged by low surface moisture, but once established, plants may have access to deeper soil moisture.

With the exception of phosphorous mineralization, total **extracellular enzyme activity (EEA)** was similar in sandy loam and loamy sand (Fig 2; Tukey HSD tests) even though plant biomass was significantly different. Extracellular enzymes will degrade slower in clay-rich soils, leading to EEA in soil even when there is little plant biomass (Burns et al, 2013). The effects of soil warming on EEA was not consistent across soil type, with higher EEA in warmed sandy loam versus lower EEA in warmed loamy sand.

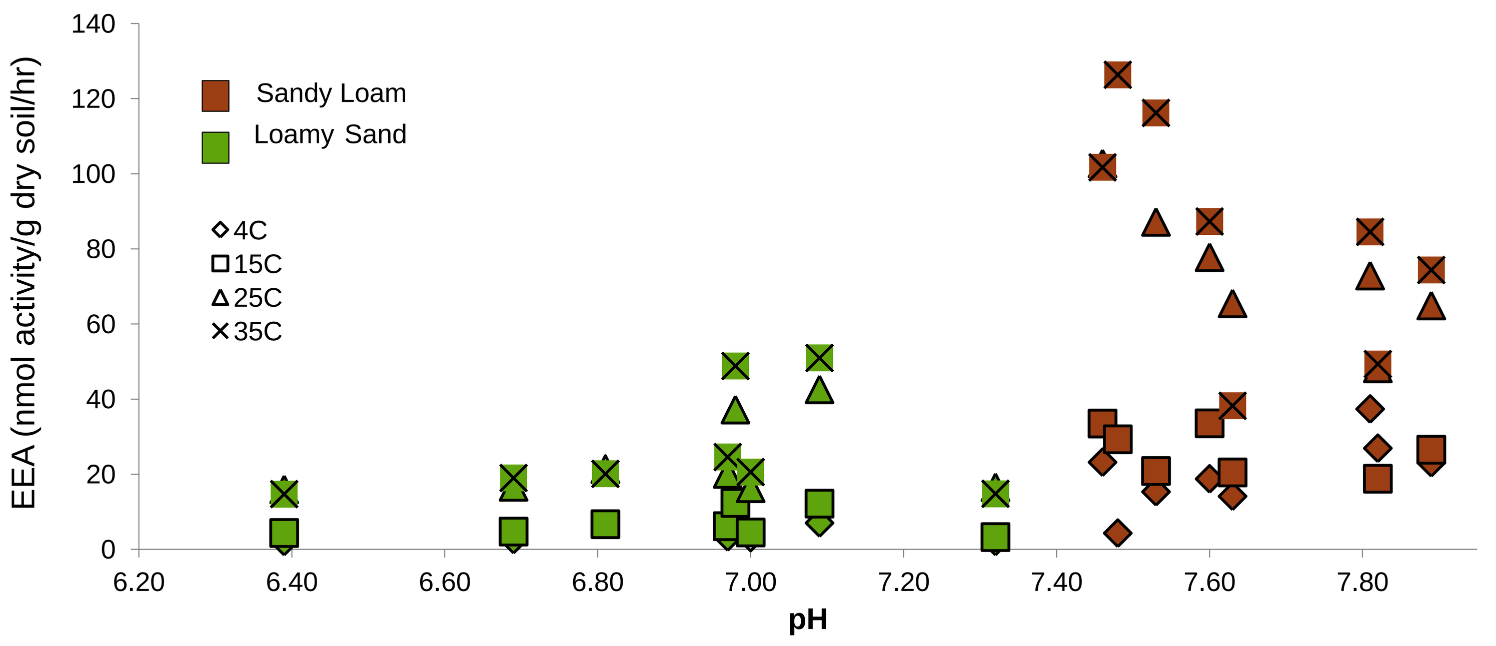


Fig. 4. EEA as a function of pH in sandy loam and loamy sand tested under four temperature treatments. Brown represents the sandy loam and green represents the loamy sand. pH ranged from 6.3-7.9; the loamy sand all had a pH below 7.32 while sandy loam was all greater than 7.46. We found greater EEA variability in the more alkaline sandy loam soils. pH is a known driver of soil microbial community composition, and previous studies have found that pH influences EEA, although the mechanism is not known at this time (Zhou, 2013).

Acknowledgements

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